

Study Unit

# Watercraft and Snowmobiles

By

**Ed Abdo**

## **About the Author**

Edward Abdo has been actively involved in the motorcycle and ATV industry for more than 25 years. He received factory training from Honda, Kawasaki, Suzuki, and Yamaha training schools. He has worked as a motorcycle technician, service manager, and Service/Parts department director.

After being a chief instructor for several years, Ed is now the Curriculum Development Manager for the Motorcycle Mechanics Institute in Phoenix, Arizona. He is also a contract instructor and administrator for American Honda's Motorcycle Service Education Department.

# Preview

Throughout this program, you've had the opportunity to learn about the exciting field of motorcycle and ATV repair. This study unit will help you to understand the basic design features of the typical snowmobile and personal watercraft. A brief history of each type of machine and some basic maintenance guidelines are provided. Keep in mind, while you read through this study unit, that we're covering only the basics of these machines. A complete program could be designed for each machine, but we'll provide the basic information you'll need to understand how these machines function.

When you complete this study unit, you'll be able to

- Understand the theory of operation for snowmobiles and personal watercraft
- Identify the different types of engines
- Understand propulsion (drive) system operation
- Understand basic maintenance
- Properly prepare snowmobiles and personal watercraft for long-term storage

# Contents

<b>INTRODUCTION . . . . .</b>	<b>1</b>
The History of Snowmobiles	
The History of Personal Watercraft	
<b>SNOWMOBILE THEORY OF OPERATION . . . . .</b>	<b>3</b>
The Snowmobile Engine	
The Snowmobile Clutch System	
The Snowmobile Chain (Gear) Case	
The Snowmobile Track	
<b>SNOWMOBILE MAINTENANCE . . . . .</b>	<b>8</b>
Running Checks	
Non-Running Checks	
Snowmobile Storage	
<b>PERSONAL WATERCRAFT THEORY OF OPERATION . . . . .</b>	<b>17</b>
Personal Watercraft Power Train	
Steering	
Cooling and Bilge Systems	
Watercraft Fuel Systems	
Electrical Circuits	
Hull Configurations and Components	
<b>PERSONAL WATERCRAFT MAINTENANCE . . . . .</b>	<b>28</b>
Hull Finish Care	
Cooling, Bilge, and Exhaust System Service	
Personal Watercraft Driveshafts	
Fuel Pumps	
Rev-Limiter	
Engine-Overheating Limiter	
Troubleshooting Symptoms	
Personal Watercraft Storage	
<b>ROAD TEST ANSWERS . . . . .</b>	<b>43</b>
<b>EXAMINATION . . . . .</b>	<b>45</b>

# *Watercraft and Snowmobiles*

## INTRODUCTION

Many motorcyclists also own ATVs, snowmobiles, and personal watercraft. Because motorcycling is a seasonal sport in most parts of the country, dealerships must offer other equipment to customers. Many motorcycle and ATV dealerships sell snowmobiles and personal watercraft to keep their customers coming into the dealership on a year-round basis. It isn't unusual to see families out on a trail ride on their motorcycles one day, on ATVs, or even at the local lake with their personal watercraft, the next. During the winter months, these same families can be found taking a ride on one of the many different snowmobiles that are available.

Throughout this study unit, we'll divide these two popular types of recreational vehicles into separate subject areas. First, we'll discuss the snowmobile and then the personal watercraft. Before categorizing the machines, we'll begin with a brief history.

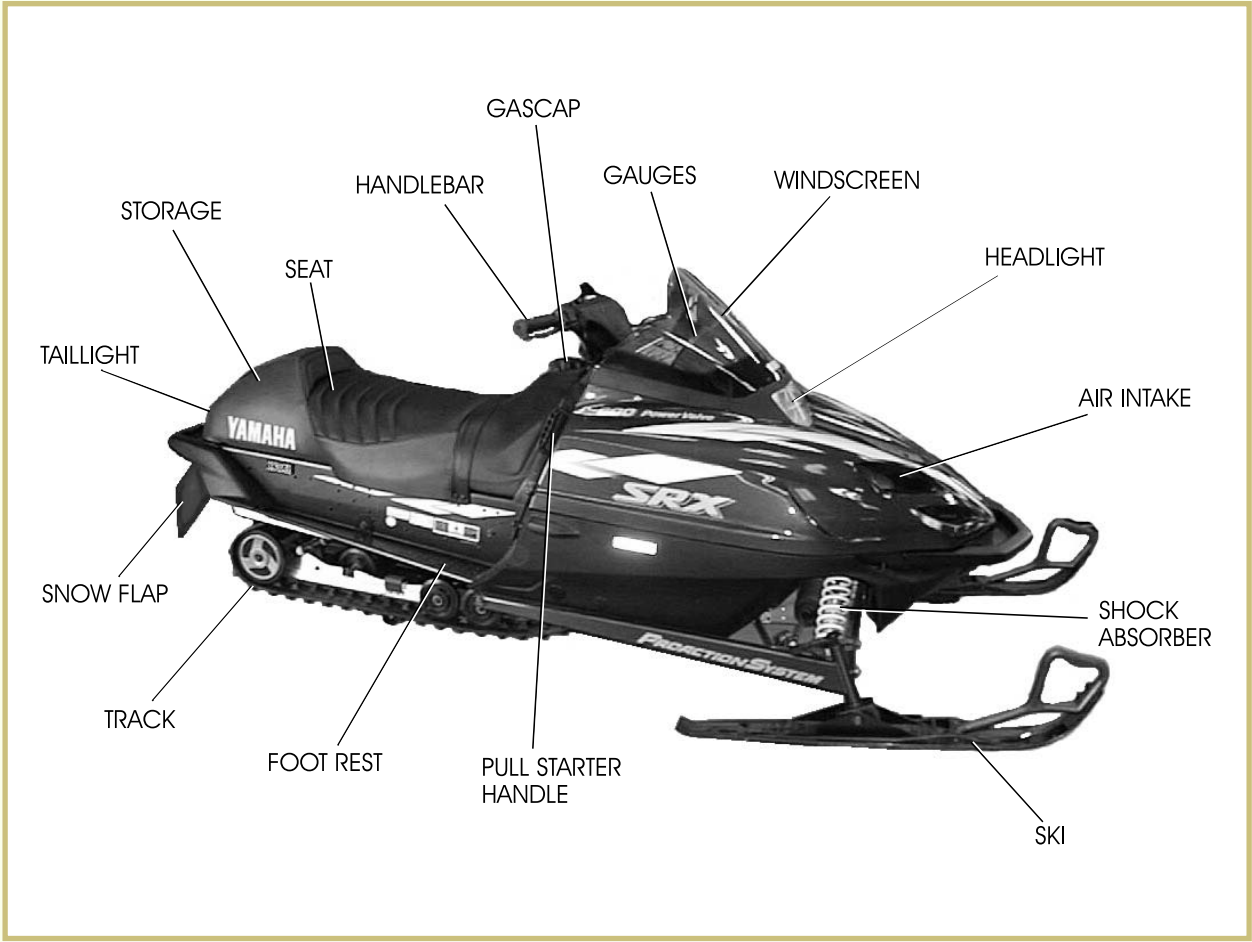
## The History of Snowmobiles

Although the snowmobile had been around for a number of years, it didn't become popular until the mid-1960s. During the mid-1960s, the snowmobile market grew to over 125 different brands. As the market became flooded with different types of machines, ranging from single-cylinder, 50 cc engines to four-cylinder, 1000 cc racing machines, the early 1970s saw a decline in the number of manufacturers. In 1976, only ten snowmobile manufacturers remained. Today, there are only four major manufacturers of snowmobiles—Arctic Cat, Polaris, Bombardier/Skidoo, and Yamaha.

Although there are fewer manufacturers, the snowmobile is still very popular. A wide variety of snowmobiles are available, ranging from the basic family machine to 150-horsepower racing machines. Snowmobiles have evolved technically and become reliable sources of recreation for millions of enthusiasts around the world ([Figure 1](#)).

## The History of Personal Watercraft

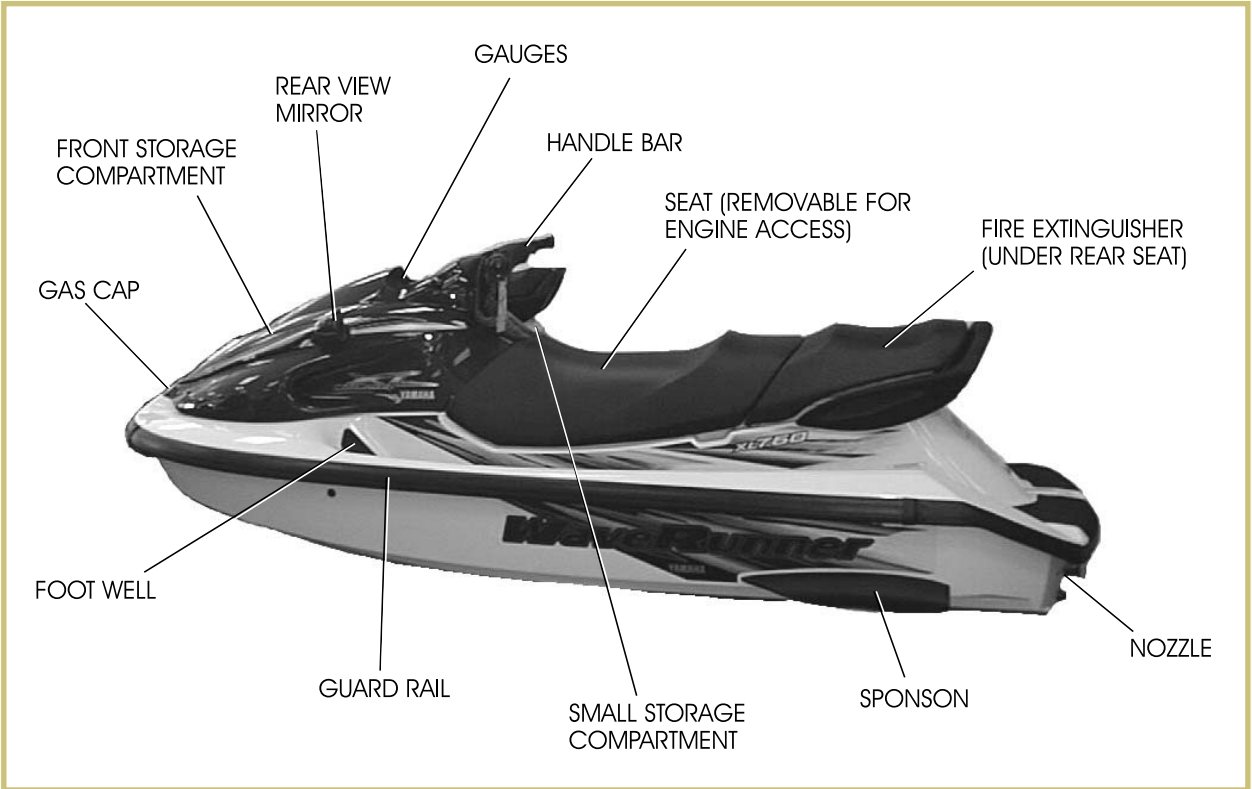
The first personal watercraft was designed and patented by a Lake Havasu, Arizona resident who sold his idea to the Kawasaki Motor Corporation. Kawasaki produced the first personal watercraft, the "Jet Ski," in 1973. This standup model, designated the JS400, had a 400 cc twin-cylinder engine and quickly became an extremely popular



**FIGURE 1—A Typical Snowmobile** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

recreational vehicle. In 1977, the JS440 was introduced and continued in production until 1992. Currently, Kawasaki produces nine different models of watercraft. In the mid 1980s, Yamaha began producing personal watercraft and used a slightly different approach than Kawasaki. Instead of the standup models, Yamaha designed a sit-down model. Today, the sit-down model is the most popular type of personal watercraft (Figure 2).

The personal watercraft industry has seen many different manufacturers entering the market since the early 1990s with the major players being Kawasaki, Polaris, Tigershark/ Arctic Cat, Bombardier/ Sea-Doo, and Yamaha. All of these personal watercraft manufacturers are currently building many different types and sizes of machines for recreation and high-performance use. You’ll also notice that many personal watercraft manufacturers are snowmobile manufacturers as well.



**FIGURE 2—A Typical Personal Watercraft (Sit-Down Model)** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

# SNOWMOBILE THEORY OF OPERATION

Unlike a motorcycle or ATV, which uses a gear-type transmission, the modern snowmobile employs a two-stroke engine that uses a variable centrifugal-clutch system. This system uses a primary centrifugal clutch, which is mounted on the engine, and a secondary clutch. The primary and secondary clutches are attached by a V-belt. The secondary clutch is attached to a jackshaft arrangement which connects the transmission to the drive. In short, the jackshaft drives a set of gears inside a chain case. This transfers the power to a drive shaft which turns the track. The power flow of a snowmobile starts at the engine crankshaft and is transferred from the primary clutch to the secondary clutch by a belt. The secondary clutch transfers this power to the jackshaft. The jackshaft sends this power to the gears in the chain case. Finally, the drive shaft turns the snowmobile’s track. As you can see, there are many moving components to this drive train. We’ll cover each one individually.

## The Snowmobile Engine

Snowmobile engines have a two-stroke internal-combustion design. They range in size from a tiny, 50 cc, single-cylinder engine to a huge, 1000 cc, 150+ horsepower, four-cylinder engine. The cooling system

designs found on these recreational vehicles can be air-cooled, fan-cooled (forced air), or liquid-cooled. Because there's no transmission attached to snowmobile engines, they're quite easy to work on. Most snowmobile engines use a reed-valve induction system to increase midrange and top-end power delivery. The engine may use one or more carburetors or none at all (fuel injected). The most popular type of carburetor found on snowmobiles is the mechanical-slide type. However, you may find some older machines with a fixed venturi carburetor. All snowmobiles use a fuel pump, either electronic or vacuum, to deliver fuel from the fuel tank to the carburetors.

## The Snowmobile Clutch System

Virtually every snowmobile uses a variable-ratio clutch-type transmission. This type of transmission automatically chooses the correct ratio, which allows the machine to quickly move from a standstill to top speed. The function of the primary and secondary clutches is similar to the function of the gears in a motorcycle transmission. There's an advantage to using clutches instead of gears. A transmission that uses gears is at a constant ratio which can't change while the gears are rotating. In a clutch-type transmission however, clutches can change ratios during operation by simply varying the diameter of the clutch pulley.

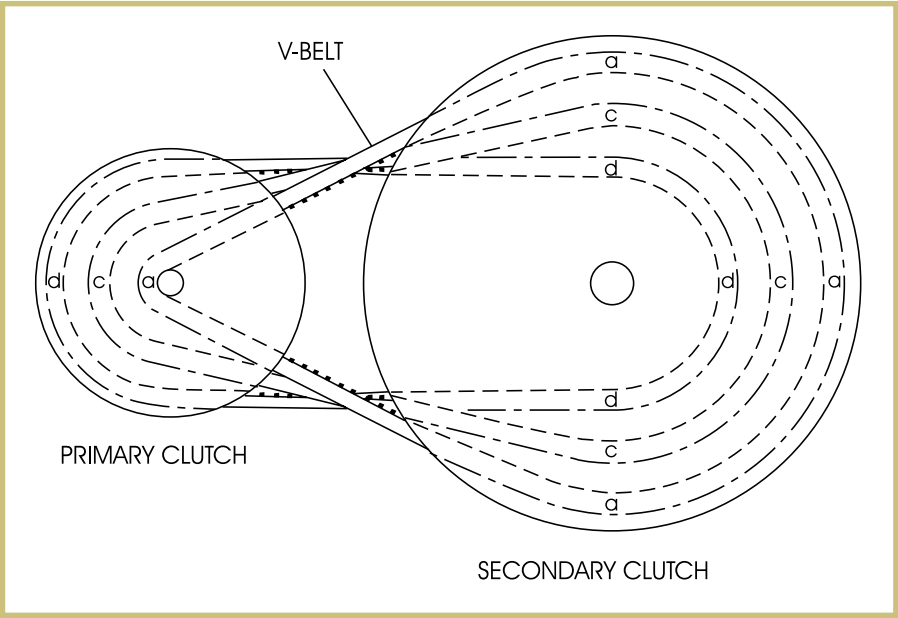
### The V-belt

A V-belt connects the primary and secondary clutches together. A V-belt is made of a rubber compound with a layer of braided synthetic cord running the entire length. V-belts provide a tremendous amount of flexibility and strength. For added strength and protection, both the inner and outer belt edges are covered with a fiber-woven cloth that's bonded to the rubber. You'll notice that the inner belt surface is ribbed, which allows the belt to flex around the small primary-clutch shaft. The belt is also tapered, from the outer to inner edge, which helps concentrate the sheave pressure on the belt and to prevent belt slippage during normal operation. The taper on the belt is necessary for proper clutch shifting.

*Clutch size* refers to the clutch diameter at the point where the V-belt makes contact. This is called "usable clutch size." The V-belt follows a circular path around the curved inner surfaces of the sheaves. As the sheaves close, the V-belt is forced outward into a larger-diameter circle. As the sheaves open, the V-belt drops in closer to the center of the clutch, and runs in a smaller circle ([Figure 3](#)).



**FIGURE 3—The variable clutch system found on snowmobiles uses a V-belt to connect the primary and secondary clutches.**  
(Image courtesy of Yamaha Motor Corporation, U.S.A.)



### The Primary Clutch

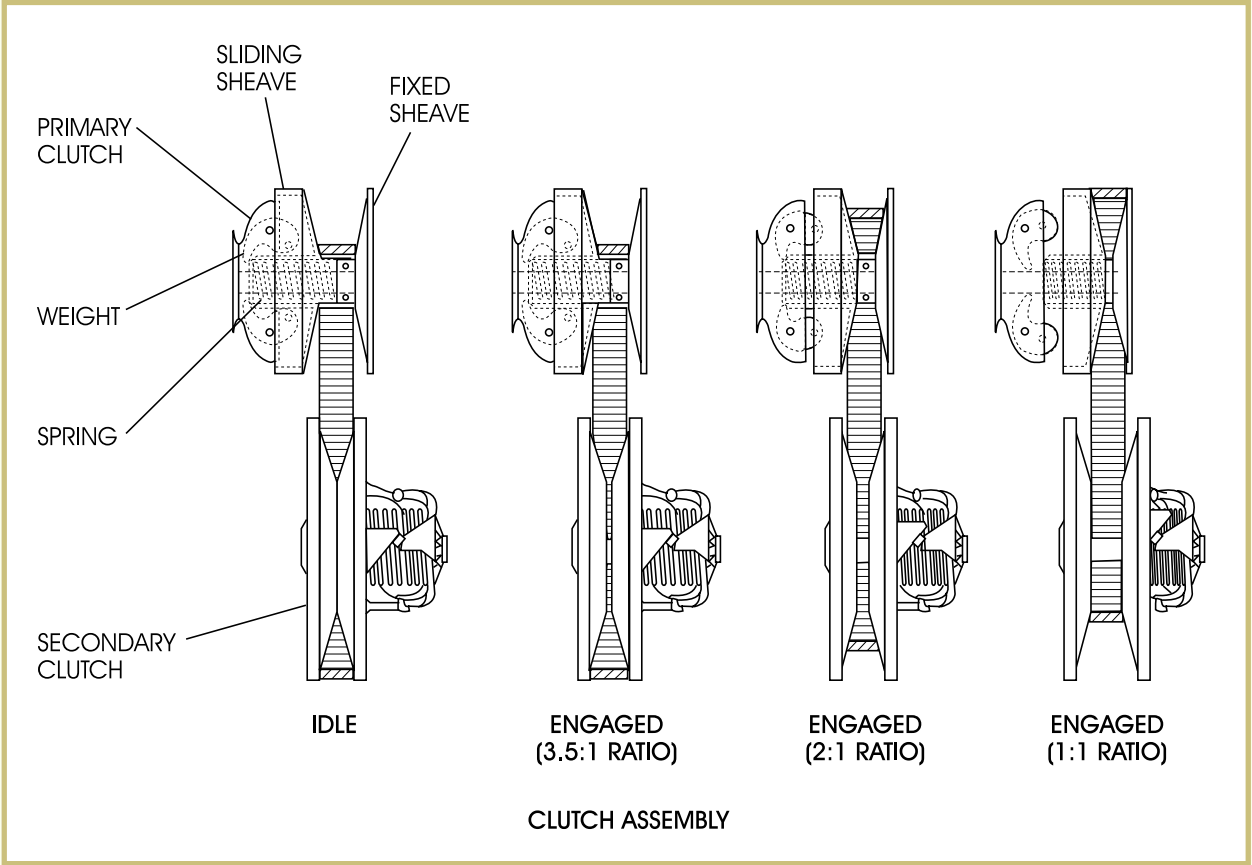
The primary clutch mounts on the end of the crankshaft and has two purposes:

- To determine engagement speed
- To maintain engine speed at a constant rpm with the power band

When idling (before engagement speed), the sliding sheave is held away from the fixed sheave by a spring. Before engagement speed, the primary-clutch sheaves are so far apart the V-belt doesn't make enough contact to move. Therefore, the V-belt isn't engaged because it's more narrow than the space between the sheaves, as shown in [Figure 4](#).

As engine rpm increases, centrifugal force begins to make the weights in the clutch move outward. The force of the weights is enough to push the sliding sheave against the primary spring. The spring has a specific preload that prevents the sliding sheave from moving until the centrifugal force becomes great enough to overcome the predetermined primary-spring pressure ([Figure 4](#)).

When the sliding sheave moves close enough to the fixed sheave, which is located on the crankshaft, the gap between the sheaves becomes narrow enough to engage the V-belt. This allows the sheaves to exert more pressure against the outside of the V-belt. The friction created at the V-belt and sheaves becomes great enough to turn the secondary clutch. Power is then transferred from the V-belt to the secondary clutch. At this time, the variable-clutch transmission achieves engagement speed ([Figure 4](#)).



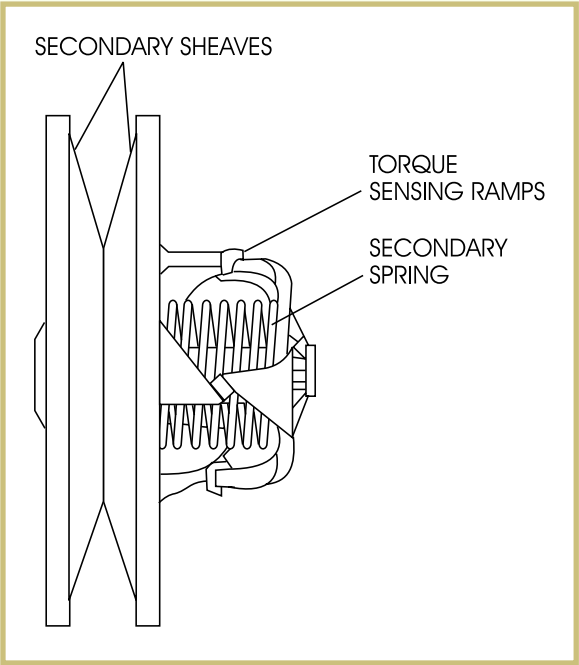
**FIGURE 4—***This illustration shows the change in the primary and secondary clutches from idle to a 1:1 ratio. (Image courtesy of Yamaha Motor Corporation, U.S.A.)*

### The Secondary Clutch

The secondary clutch is designed to sense the load requirements of the track, and reacts by shifting to a ratio that allows the engine to operate within its power band. At first, the secondary clutch is turning much more slowly than the primary clutch. Because the secondary clutch drives the track, the track will also go faster in relation to the speed of the engine.

The secondary clutch uses a torque spring and sensing ramps (Figure 5) to maintain the proper V-belt pressure, and to maintain the proper clutch ratio. The secondary spring forces the secondary sheaves closed, making the V-belt ride on the outer circumference of the sheaves. As the primary clutch shifts to a higher ratio, the belt rides to the outer perimeter of the primary sheaves. As this occurs, the belt pressure tries to pull the V-belt down between the secondary sheaves, causing a higher ratio. The spring and cam are designed to prevent the sheaves from being forced apart by the belt pressure until it's enough to overcome the predetermined spring pressure, thus allowing maximum use of the primary gear.

**FIGURE 5—Secondary clutch springs and ramps react to the torque on the clutch. As the springs and ramps move, the clutch opens and allows the belt to slide down toward the center portion of the clutch.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)



The secondary spring prevents the V-belt from being pulled between the sheaves by forcing the clutch sheaves closed. This spring is preloaded with both an axial and a torsional pressure via the cam, or spring seat. Most of the force against the sheaves is in the form of torque, rather than pressure. As belt pressure pulls the belt between the sheaves, the cam twists on its ramps and applies a predetermined amount of pressure on the V-belt at all times.

## The Snowmobile Chain (Gear) Case

The snowmobile chain case houses both the drive sprocket and driven sprocket, as well as the primary chain and a chain tensioner arrangement. These components are lubricated by a hypoid gear lubricant, similar to that used in the final drive gear case on a shaft-driven motorcycle. The drive sprocket is attached to the jackshaft of the machine, while the driven sprocket attaches to the drive shaft, which drives the track. The gear ratio between the jackshaft and the drive shaft can be changed for different snowmobile uses. In many cases, if a gear ratio change is desired, both the sprockets and the chain must be replaced.

## The Snowmobile Track

The track on a snowmobile is made of a rubber and fiber compound similar to the materials found in a V-belt. Some tracks have metal rods that are used to help make the track more durable. These tracks are extremely durable and long lasting, as long as they're properly maintained.

# Road Test 1



At the end of each section of *Watercraft and Snowmobiles*, you'll be asked to check your understanding of what you've just read by completing a "Road Test." Writing the answers to these questions will help you review what you've learned so far. Please complete *Road Test 1* now.

1. The jackshaft connects the \_\_\_\_\_ to the \_\_\_\_\_.
2. The primary and secondary clutches are attached by a \_\_\_\_\_.
3. What is used to lubricate the chain and sprocket in a snowmobile gear case?  
\_\_\_\_\_
4. The secondary clutch is mounted on the \_\_\_\_\_.
5. Cooling systems used on snowmobiles can be \_\_\_\_\_, \_\_\_\_\_, or \_\_\_\_\_ cooled systems.
6. *True or False?* Some snowmobiles use the fixed venturi type of carburetor.
7. The primary clutch used on a snowmobile mounts on the \_\_\_\_\_.
8. *True or False?* When a snowmobile begins moving, the primary clutch is moving much slower than the secondary clutch.

[Check your answers with those on page 43.](#)

## SNOWMOBILE MAINTENANCE

This section of your study unit focuses on snowmobile maintenance. We'll begin with running checks, which are performed on the engine. Then we'll discuss non-running checks which pertain to snowmobile chassis maintenance. When you become a seasoned technician, you'll be able to correctly perform these checks in less than one hour.

### Running Checks

#### Oil-Injection Systems

Most snowmobiles use an oil-injection system. If the model that you're maintaining has an oil-injection system, ensure that the oil tank is filled during the servicing procedure.

## Carburetor Adjustments

In comparing motorcycle and snowmobile carburetor adjustments, you'll find several similarities. To adjust the carburetor(s) in a snowmobile, begin by checking and adjusting the throttle play, which you would perform in the same manner as on a motorcycle or ATV. (Specifications for play are found in the appropriate service manual.) Be sure to set the low-speed mixture screw to the manufacturer's recommended initial setting, which you can also find in the appropriate service manual. If you have a snowmobile with multiple carburetors, it's important that you verify that they're properly synchronized. This is required for good performance and customer satisfaction. After all other adjustments have been made, set the idle speed to the specified setting and recheck the low-speed mixture screw for proper adjustment.

## Coolant Condition

You'll also find similarities between motorcycles and snowmobiles when you're checking the condition of the coolant. With liquid-cooled snowmobiles, be sure to check the coolant level and fill as required. To ensure that the coolant is at the proper level, perform this procedure several times while the engine is running and hot. As with motorcycles, always use a 50-50 mixture of ethylene-glycol and distilled water.

Prior to cleaning coolant systems, refer to the service manual or any technical bulletins regarding coolant level and bleeding. On units that have bleed screws at the rear of the system, raise the back of the snowmobile to trap air at the bleed points. Remember, air is bled from the highest part of the cooling system.

*Note:* You should also check the headlight and taillight for proper operation, and check the headlight aim.

## Non-Running Checks

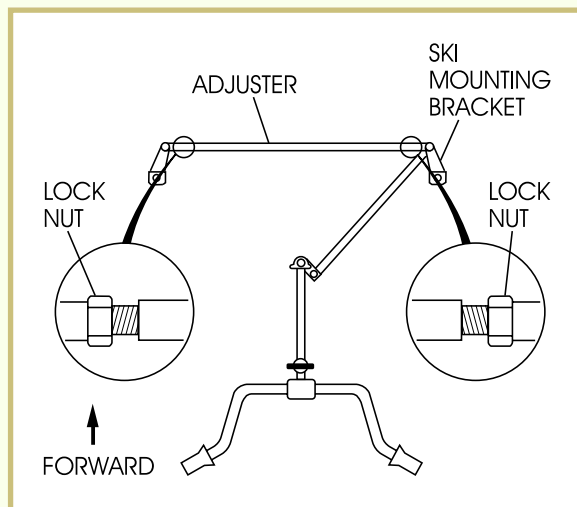
### Snowmobile Steering Alignment

Each time the snowmobile is serviced, check and adjust the steering and ski alignment. Proper alignment is the most important item for proper snowmobile handling/steering. Adjusting this area of the snowmobile involves verifying the proper operating condition of the front suspension, handlebar, skis, and ski runner. Note that some snowmobile models use conventional oil-dampened shocks in addition to springs; these items must be checked for wear.

A proper steering alignment ([Figure 6](#)) ensures that the handlebar is straight when the skis are straight. This adjustment is performed in conjunction with the ski alignment. Skis should be parallel with each

other, as well as with the track. Properly aligned skis point straight ahead, while misaligned skis point “toe-in” or “toe-out.” “Toe-in” skis plow through the snow, while “toe-out” skis dart from one side to the other. Misaligned skis reduce speed and affect the handling of the snowmobile, resulting in a potential hazard. Any damaged steering components must be repaired immediately. Be sure to check the condition of the ski runners for broken welds and dents and ensure that they’re fastened securely.

**FIGURE 6—Proper steering alignment requires adjustment of various lock nuts and linkages.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)



## Brakes

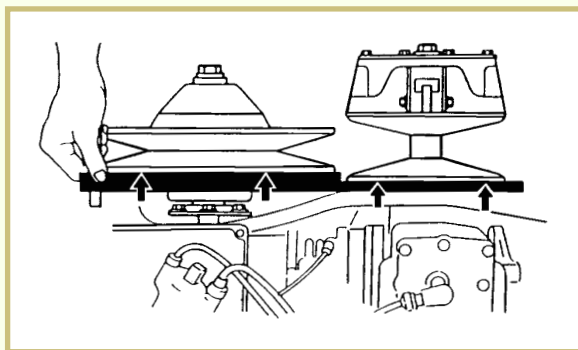
As with any vehicle, the brakes should be checked periodically. You should ensure that the brake pads are in good working condition. You should also check the brakes for proper spacing and operation; squeeze the lever to determine if the brake pads and spring preload are functioning properly. Some models use hydraulic self-adjusting brakes; inspect these for pad wear. Refer to the appropriate service manual for specifications and proper adjustment procedures.

## Clutch Adjustments

Proper clutch adjustments are needed to maintain good clutch operation and to prolong V-belt life. When inspecting the clutch system on a snowmobile, you need to perform three basic checks—clutch offset, clutch center-to-center distance, and clutch alignment.

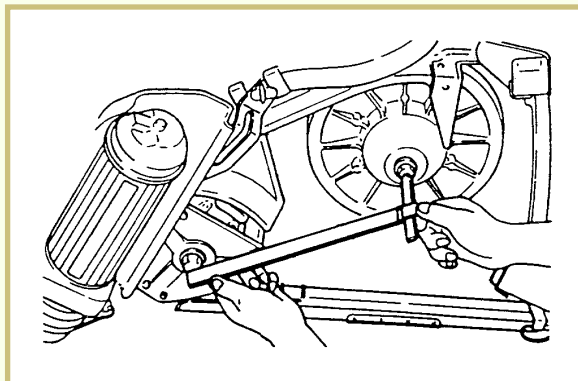
**Clutch offset.** The primary and secondary clutches must have a specific amount of offset (Figure 7). Offset is required because the fixed sheave on the primary clutch is on the opposite side of the fixed sheave on the secondary clutch. Providing the correct amount of offset will keep the belt pressure against the fixed sheaves as the sliding sheaves change position. An excess amount of offset can result in uneven wear of the V-belt.

**FIGURE 7—The technician is measuring clutch offset in this illustration.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)



**Clutch center-to-center distance.** Clutch center-to-center distance is the measurement between the center of the primary clutch and the center of the secondary clutch (Figure 8). Engine torque can cause the center-to-center distance to shorten as the primary clutch is pulled towards the secondary clutch, which will hinder clutch performance. Some performance models use an *engine break*, which is a piece of metal that prevents the engine from moving under excessive torque.

**FIGURE 8—The technician is measuring clutch center-to-center distance in this illustration.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)



**Clutch alignment.** Clutch alignment is the adjustment made to bring both clutches in line. Proper alignment is achieved by moving the engine on its mounts so the engine's crankshaft is in a parallel line with the jackshaft. Proper alignment ensures that the V-belt runs in a straight line. If the crankshaft and jackshaft are incorrectly aligned, the V-belt will have a tendency to be pulled to one side. This will create uneven side pressure and will prematurely wear out the V-belt, as well as allow incorrect clutch shifting and clutch wear. There are two types of misalignment—the crankshaft and jackshaft may not be parallel, or the shafts may not be on the same plane. When you look down on the engine and jackshaft, the shafts should be parallel with each other. Also, while you look at the crankshaft and jackshaft ends, both shafts should be on the same (level) plane. Incorrect alignment occurs if the engine is mounted higher on one side. If this condition occurs, you'll need to shim the engine to correct it.



Clutch alignment should be done during general maintenance. This procedure must also be performed any time the engine is moved or removed from the chassis. Clutch alignment is measured with a special alignment tool available from snowmobile manufacturers. To measure the clutch offset, place the clutch-alignment tool behind the clutch sheaves from the secondary sheave to the primary sheave. Hold the tool flat against both edges of the secondary sheave at the tip and check for any gap between the tool and the primary sheave. If there's more than the specified amount of clearance, an adjustment will be necessary. To make sure the engine is level with the jackshaft, place the tool at the bottom of the sheaves and do the same check. If the alignment is off at the bottom, shim the engine so that both alignment measurements are the same.

## V-Belt Adjustments

In order to maintain proper clutch operation, when performing maintenance, you should also check the V-belt.

**V-belt width.** Belts will wear with use, and when the width of a belt is worn beyond the specified amount, it must be replaced. V-belt width is measured with a Vernier caliper. The manufacturer will have the specifications for the correct belt width in the appropriate service manual.

**V-belt length.** V-belts must also be checked for proper length. This is accomplished simply by using a measuring tape and measuring the belt after it has been removed from the clutches. V-belts can stretch and are no longer useful when they're stretched beyond their specified length.

**V-belt life.** There's no specific time or mileage at which the drive belt will wear out. Length of belt service will depend on the type of use. With proper maintenance, care, and correct operation, a V-belt should last for an average of 500 to 1000 miles. It isn't uncommon, however, to see a V-belt destroyed in only a few miles. Usually, this is due to improper operation, or the conditions in which the snowmobile is being used. It's a good habit for an experienced snowmobile technician to instruct novice snowmobilers on proper operation of their machine to prolong the life of the V-belt. For example,

- Many snowmobilers like to stop on the incline of a hill and then accelerate uphill to feel the power and traction. Just a few starts like this can ruin a V-belt.
- Some new snowmobilers are uncomfortable when riding fast, so they ride slower, usually right at engagement speed. This causes the clutches to constantly shift, leading to belt slippage and finally belt failure.



## Drive Chain and Sprockets

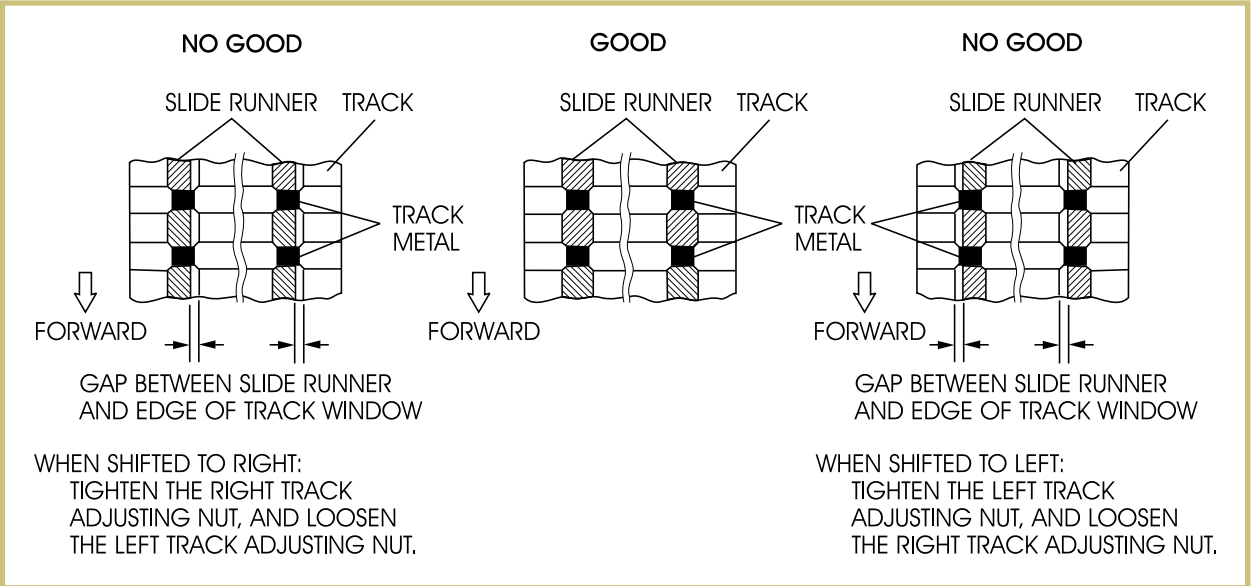
The drive train and sprockets are two other areas you need to check and adjust when necessary. The chain should have a predetermined amount of play, specified by the individual manufacturer. You need to check and adjust the chain tension inside of the chain case. Rocking the secondary clutch back and forth after removing the V-belt is an easy way to detect a loose or a tight chain. Adjustments to the chain are made by moving the chain adjuster, which is attached to the chain case. Also, check the chain case oil level to verify that the main seal and gasket are in good condition. If the chain case oil level is low, there's usually a problem with the main seal or gasket.

While working on this section of the snowmobile, check the drive sprocket condition and alignment. When drive sprockets are misaligned or damaged, they'll eventually cause track damage. Perform this inspection while checking the track tension. The snowmobile should be turned on its side to view the drive sprockets.

## Track Tension And Alignment

Traction is a major player in the performance of a snowmobile. An improperly adjusted or misaligned track will cause problems with performance and increase the chances of premature component wear.

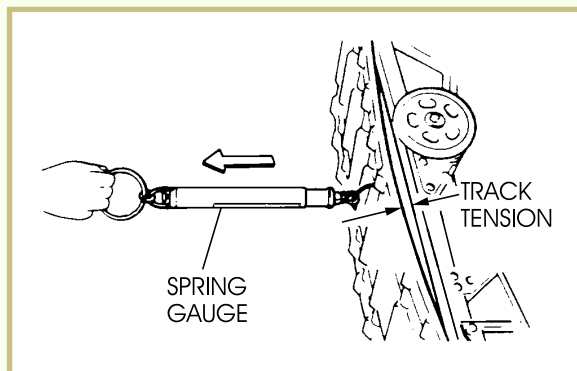
Inspect the tension, alignment, and general condition of the track. To check the track tension and alignment, raise the rear of the snowmobile and support it on jackstands. Start the engine and spin the track for a few seconds, then turn the engine off and check the track alignment by confirming the alignment of the slide runner. All distances should be equal, as shown in [Figure 9](#).



**FIGURE 9—The center illustration demonstrates proper track alignment.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

When checking track and slide runner alignment and condition, remember to check the condition and alignment of the guide wheels at the front of the track. Once you've determined that the track alignment is good, you can check for proper track tension. To do this, you'll need a ruler and a spring gauge (Figure 10). As always, you should refer to the appropriate service manual for specifications. If track tension is incorrect, you'll notice a loss in performance that will eventually damage the track. If the track has studs installed, compare the stud pattern with that included in the appropriate owner's manual. Improper track studding can cause track and chassis damage. If the track has been replaced or removed for any reason, ensure that it has been installed in the proper direction.

**FIGURE 10—The technician is measuring track tension in this illustration.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

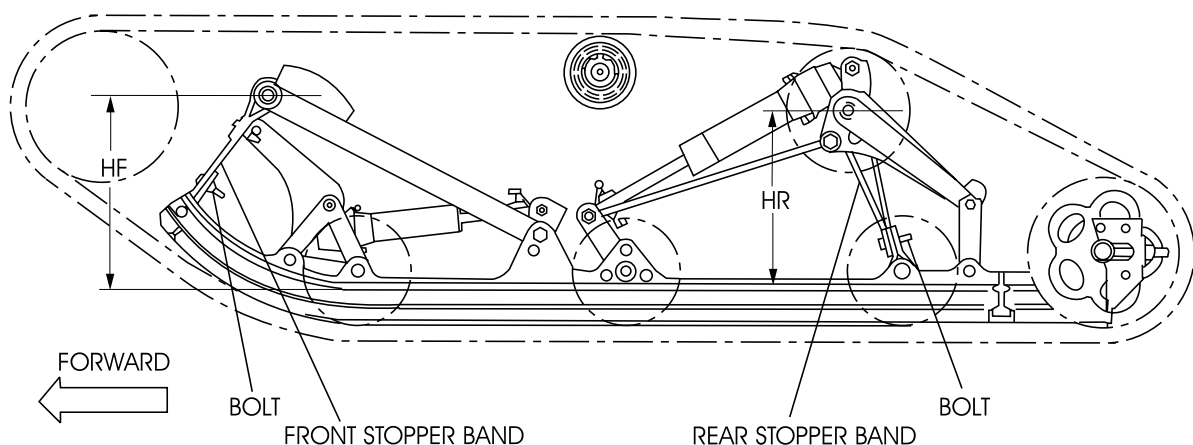


After inspecting the track, you should now check the condition of the track guide, wheels, and bearings. Ensure proper operation of the track guide clip, and inspect wheel and bearing condition. The wheels should turn freely without any unusual noise. Always replace any damaged wheels or wheel bearings. The slide runners, better known as “Hyfax,” are long plastic guides attached to the suspension frame to protect it from running against the snowmobile track. The Hyfax should be inspected on a regular basis for wear and damage, and replaced when necessary.

## Front and Rear Suspension Adjustments

Improper suspension adjustment substantially reduces a snowmobile's stability, steering, and performance. Always consider the conditions in which the snowmobile is used and adjust the suspension accordingly.

Adjust the snowmobile's suspension (Figure 11) to the softest possible setting without causing the snowmobile to bottom out. A setting that's too hard is uncomfortable and provides poor handling. A setting that's too soft provides poor handling, causes speed loss, and causes damage over rough terrain. For general use, comfort is a primary concern, and for performance, handling is the objective. A compromise between these two must be made, depending upon the kind of riding and terrain.



**FIGURE 11—Tightening or loosening the bolts on the rear suspension of a snowmobile will increase or decrease the suspension's spring tension.** (Image courtesy of Yamaha Motor Corporation, U.S.A.)

You should always test-ride a snowmobile after you've serviced it. Pay close attention to clutch engagement rpm and shift rpm. Check for vibration and the overall feel of the snowmobile.

Before delivering any machine to the customer, you should always clean and polish it. Ensure that all fingerprints and grime have been removed. A good rule of thumb is to deliver a machine cleaner than you received it. A technician who is recognized for delivering quality back to his or her customer will hold a definite advantage in the marketplace.

## Final Checks

Ensure all nuts and bolts are secure and all lock tabs and coffer pins are in place. If you removed a lock tab or coffer pin during servicing, be sure that you installed a new one.

## Snowmobile Storage

There are five basic steps you should follow to properly prepare a snowmobile for storage. Performing these steps will prolong the life of a snowmobile and prevent heavy repair.

**Cleaning.** Remove all dirt, grease, mud, and grime that the machine has collected internally and externally. Clean the snowmobile with a quality degreaser and soap and water. When you've finished cleaning, ensure everything is thoroughly rinsed.

**Lubricate the chassis.** In order to fight corrosion, lubricate all of the external moving parts of the machine with a high-quality general-purpose lubricant. Ensure lubrication of the suspension linkages and all pivot points on the snowmobile.

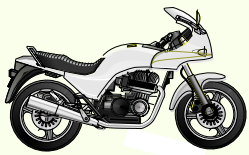
**Fuel conditioning.** As with storing a motorcycle in the off-season, storing a snowmobile during the summer months requires that you properly prepare the fuel. The reason for this is that alcohol, which is found in many fuels, can carry moisture into the engine. Moisture corrodes internal engine parts. The alcohol in the fuel also reduces the protection that's provided by rust inhibitors (added to most oils). Thus, proper storage techniques are essential to prevent damage to the internal components of a snowmobile engine.

In the summer, many snowmobile owners will start the engine of their snowmobile every few weeks instead of following proper storage procedures. This is sometimes more harmful than ignoring storage procedures altogether, because one of the major byproducts of the internal-combustion process is water. By starting the engine every few weeks, even more harmful moisture enters the engine than if the fuel were just left in the tank over the summer. Before putting a snowmobile away for the summer, you need to fill the fuel tank completely and use a gasoline stabilizer to prevent the fuel from "varnishing." After adding conditioner to the fuel, you should start the engine and run it long enough to allow the conditioner to reach the carburetor.

**Internal engine-storage preparation.** During extended periods of storage, most manufacturers will recommend an engine-storage procedure that involves spraying a type of oil into the engine through the carburetor to protect the internal engine components from moisture. This procedure is known as "engine fogging" and must be performed in a well-ventilated area. On single-cylinder engines, you'll need to gain access to the mouth of the carburetor. After the engine has warmed up and is running, spray the manufacturer-recommended pressurized fogging agent into the mouth of the carburetor for the specified amount of time. Don't be surprised to see a lot of smoke coming out of the exhaust system! This procedure must be performed intermittently to prevent the engine from stalling. When working on multicylinder engines with individual carburetors, it's necessary to repeat the procedure in each of the individual cylinders.

**Waxing.** In order to prevent body corrosion, wax all of the painted surfaces with a high-quality wax. This will keep the machine looking like new.

# Road Test 2



1. *True or False?* On a liquid-cooled snowmobile, the coolant mixture should have more antifreeze (ethylene glycol) in it than a liquid-cooled motorcycle because of the cold temperatures that it's operated in.
2. A snowmobile with excessive "toe-in" will tend to \_\_\_\_\_.
3. A snowmobile with excessive "toe-out" will tend to \_\_\_\_\_.
4. On a snowmobile, what can result from excessive clutch offset?  
\_\_\_\_\_
5. If a customer's snowmobile has a clutch-related problem that requires troubleshooting, what's the first thing to check?  
\_\_\_\_\_
6. Describe an easy way to check the chain tension in a chain case on a snowmobile?  
\_\_\_\_\_  
\_\_\_\_\_
7. If the chain case oil level is low, where will the problem most likely be located?  
\_\_\_\_\_
8. What two tools are required to properly check snowmobile track tension?  
\_\_\_\_\_
9. What substance is used to raise the octane level in gasoline and also causes a storage problem on a snowmobile?  
\_\_\_\_\_
10. Most manufacturers will recommend spraying a type of oil into the engine through the carburetor to protect the internal engine components from moisture during extended periods of storage. What is this procedure known as?  
\_\_\_\_\_

Check your answers with those on page 43.

## PERSONAL WATERCRAFT THEORY OF OPERATION

The personal watercraft was patterned after jet-drive boats which were first developed in the early 1960s. Personal watercraft have a two-stroke engine with a water cooling system that uses the water being ridden on as a coolant for the engine. There are a few single-cylinder machines, but most watercraft engines are multiple-cylinder designs that use two or three cylinders. Current displacement ranges are from 500 cc to 1100 cc; engines have horsepower ratings of 50 hp

to over 120 hp. All current watercraft use a fixed venturi carburetor system, and most use one carburetor for each cylinder on the engine. The induction systems used are reed-valve and rotary-valve designs.

Propulsion in a personal watercraft is fairly simple. A jet pump brings in a tremendous amount of water (from under the craft), cycles it through a powerful rotating pump, and then expels the water. Two jet pump designs exist—the axial flow and the mixed flow.

## Personal Watercraft Power Train

Figure 12 demonstrates a typical configuration of a watercraft power train. The basic arrangement of the engine and jet pump are virtually identical for all manufacturers of personal watercraft. The engine and driveshaft couplers connect the engine to the driveshaft. There's no gear reduction. Rubber dampers separate the couplers. The driveshaft drives the impeller (described below), which is located inside of the pump body housing, and draws water into an opening in the hull via a suction and intake casting. The water is forced from the pump housing through the outlet nozzle.

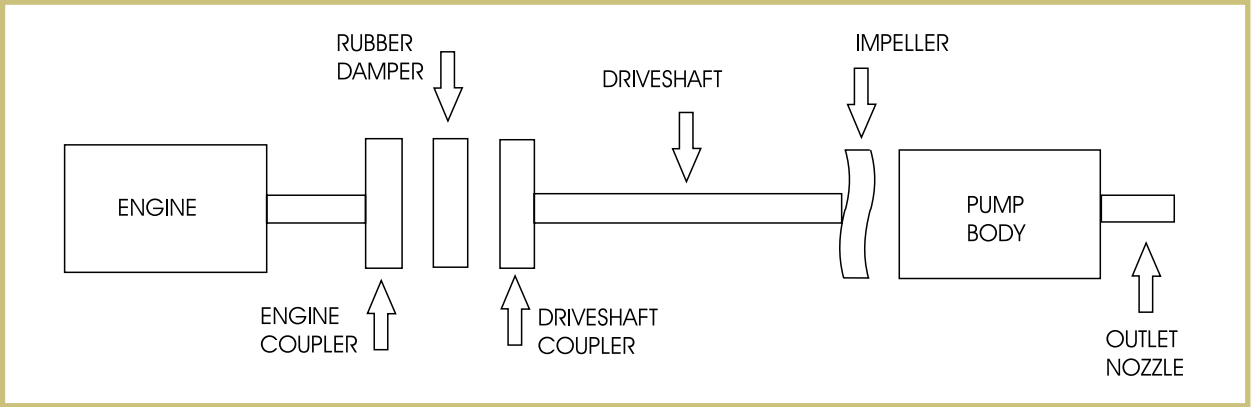
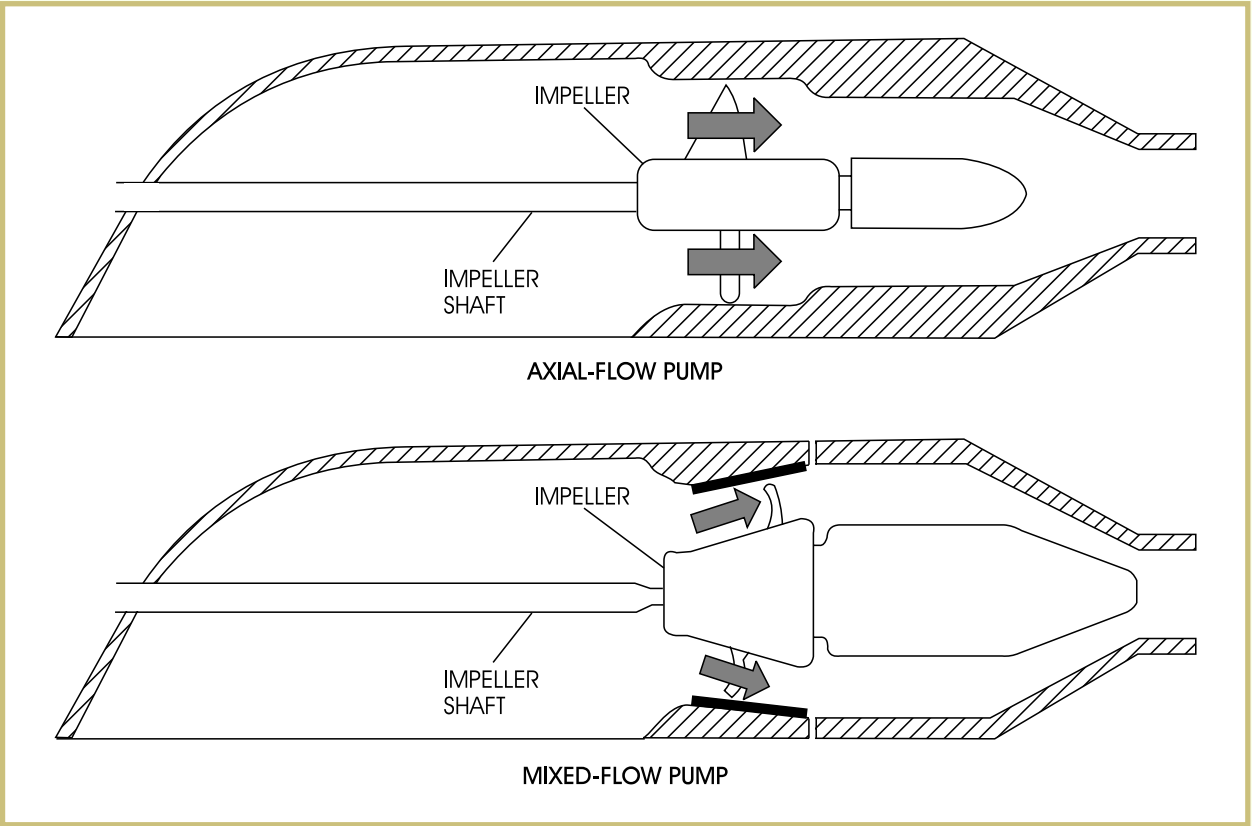


FIGURE 12—The basic components of a watercraft power train are shown here.

### Axial-Flow Pumps

An *axial-flow pump* is designed to operate at a high engine rpm and is used in racing applications, where top speed is important. An axial-flow design actually performs best at a high engine rpm. The water in this type of pump is brought in and dispersed straight through the pump housing as shown in Figure 13.



**FIGURE 13—Axial- and Mixed-Flow Jet Pumps** (Courtesy Kawasaki Motor Corp., U.S.A.)

### Mixed-Flow Pumps

The *mixed-flow pump* design performs with high efficiency at low engine rpm, where high thrust is needed for taking off from a stopped position. Many experts in the field of personal watercraft consider the mixed-flow pump design to be the most efficient. On this type of jet pump, the water is directed outward of the pump housing and then back to the center, as [Figure 13](#) illustrates.

### Watercraft Impellers

The impeller on a personal watercraft differs from a propeller on a boat, in that *propellers* pull water and *impellers* push water. The impeller provides thrust by using a combination of water flow and water pressure (in a precision closed area). The blades of an impeller overlap, thereby trapping water and forcing it through the impeller, and finally into the duct and nozzle.

### Nozzle

The nozzle on a watercraft is comprised of two separate pieces. A pivoting piece is needed for steering the craft and a tapered portion is part of the jet-pump housing.

## Forward, Neutral, and Reverse

Many personal watercraft have a gate, activated by a cable, that controls the flow of water. A fully open gate allows the water to flow through the nozzle and moves the watercraft in a forward motion. A partially closed gate allows some of the water flowing from the pump to flow outward through the nozzle while the rest of the water is deflected downward and forward. This creates a neutral position because the water is being equally dispersed in both forward and aft directions. A fully closed gate completely deflects the water in a downward and forward motion, allowing the watercraft to move in reverse.

## Steering

Steering a personal watercraft is accomplished through motorcycle-type handlebars. The handlebars are attached to a cable, which turns the nozzle at the pump housing.

## Cooling and Bilge Systems

Most jet pumps have two hoses attached to the housing. One of these hoses is used for the cooling system and diverts some of the water coming through the pump to the exhaust manifold of the engine. This is the hottest part of the engine, and the water is used to cool the block during operation. The other hose is used to siphon the water out of the watercraft hull and is known as the *bilge system*.

## Watercraft Fuel Systems

Personal watercraft use pressurized fuel systems. Although they're vented to the atmosphere, they use a one-way check valve to maintain pressure when the engine is operating (allowing the fuel system to function correctly).

### Fuel Tanks

The fuel tank is generally made of plastic and has a capacity of 4 to 15 gallons depending upon the size of the machine. As stated below, there are normally four separate lines that are attached to the personal watercraft fuel tank:

- The vent line, which is easily identified by the one-way check valve
- The main fuel line, which delivers the fuel to the carburetors when the fuel petcock is in the "on" position



- The reserve line, which delivers the fuel to the carburetors when the fuel petcock is in the “reserve” position
- The return line, which returns the unused fuel that’s flowing into the carburetors (since they don’t have float bowls)

*Note:* There’s one more line, called the *pulse line*, that’s an indirect part of the fuel system. The pulse line is used to operate the *fuel pump diaphragm*, which causes the fuel to flow from the fuel tank to the carburetor system.

## Carburetors

As mentioned earlier, carburetors used on personal watercraft are fixed venturi designs. Although the fixed venturi carburetor has a simple design, the operation is precise. As the name suggests, the carburetor is fixed and doesn’t have a slide for changing the size of the venturi. A throttle plate controls the amount of air entering the engine intake tract. When the rider opens the throttle control for an increase in speed, the throttle valve opens between the carburetor and the engine intake tract, allowing more air and fuel to enter the engine combustion chamber. The most popular fixed venturi carburetor found on personal watercraft is the Mikuni Super BN carburetor.

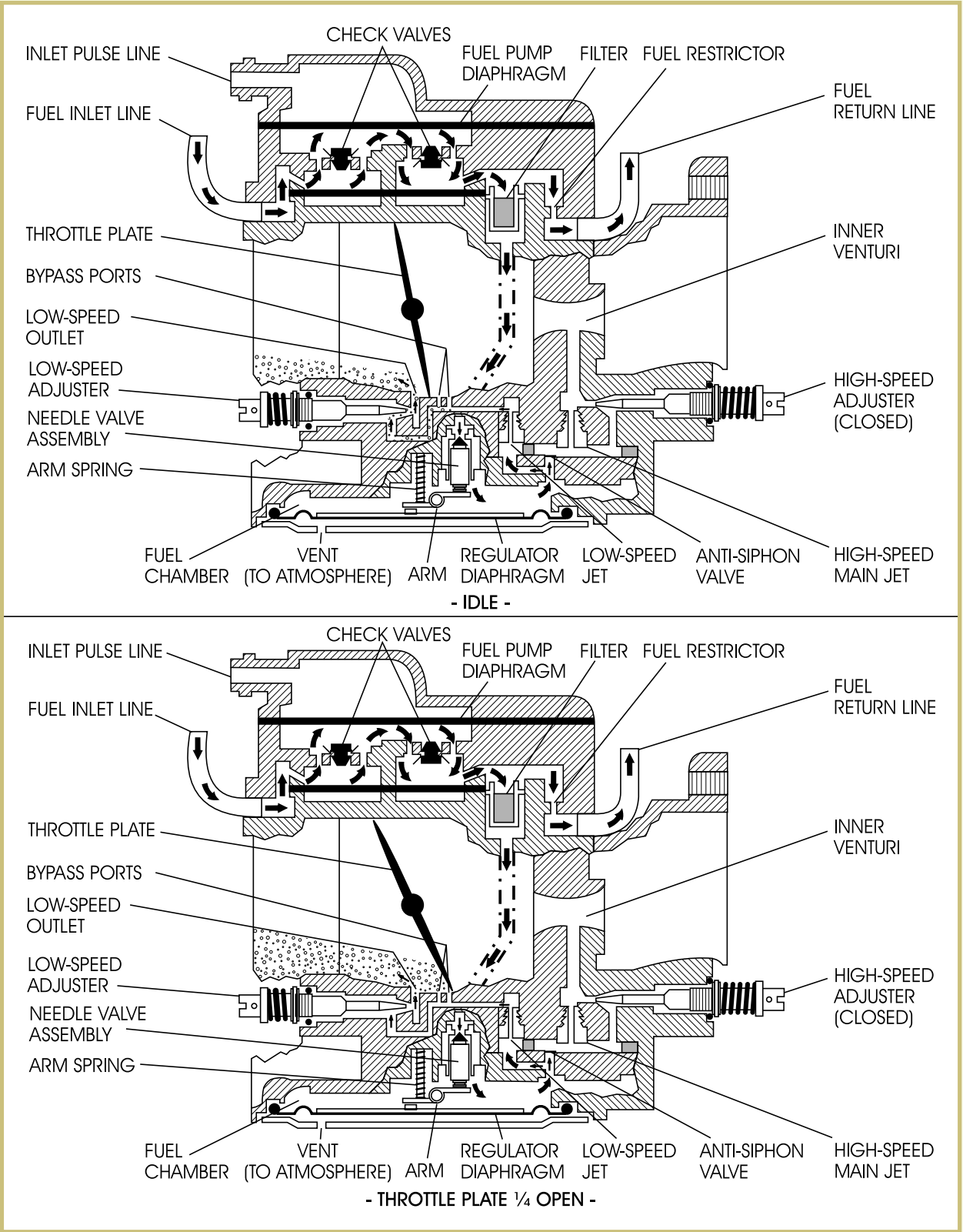
Through the cutaway illustration in [Figure 14](#), we can learn how this type of carburetor functions under various conditions. The fuel pump diaphragm draws fuel via the fuel inlet line through a check valve. The diaphragm then forces the fuel through another check valve and filter. Any excess fuel is diverted back to the fuel tank via the fuel return line. Also, a fuel restrictor is used to regulate fuel pressure for the fuel pump.

The fuel that passes through the fuel filter goes straight to the needle-valve assembly and then into the fuel chamber area. The regulator diaphragm, arm spring, arm, and vent control the flow of fuel into the fuel chamber. These components, along with the needle valve, comprise the regulator portion of a Mikuni Super BN carburetor. Actually, the Mikuni Super BN is part carburetor and part fuel regulator. The fuel regulator controls the flow of fuel at low speeds (idle to  $\frac{1}{2}$  throttle), and the carburetor portion controls the flow of fuel at higher speeds (from  $\frac{1}{2}$  throttle to full throttle).

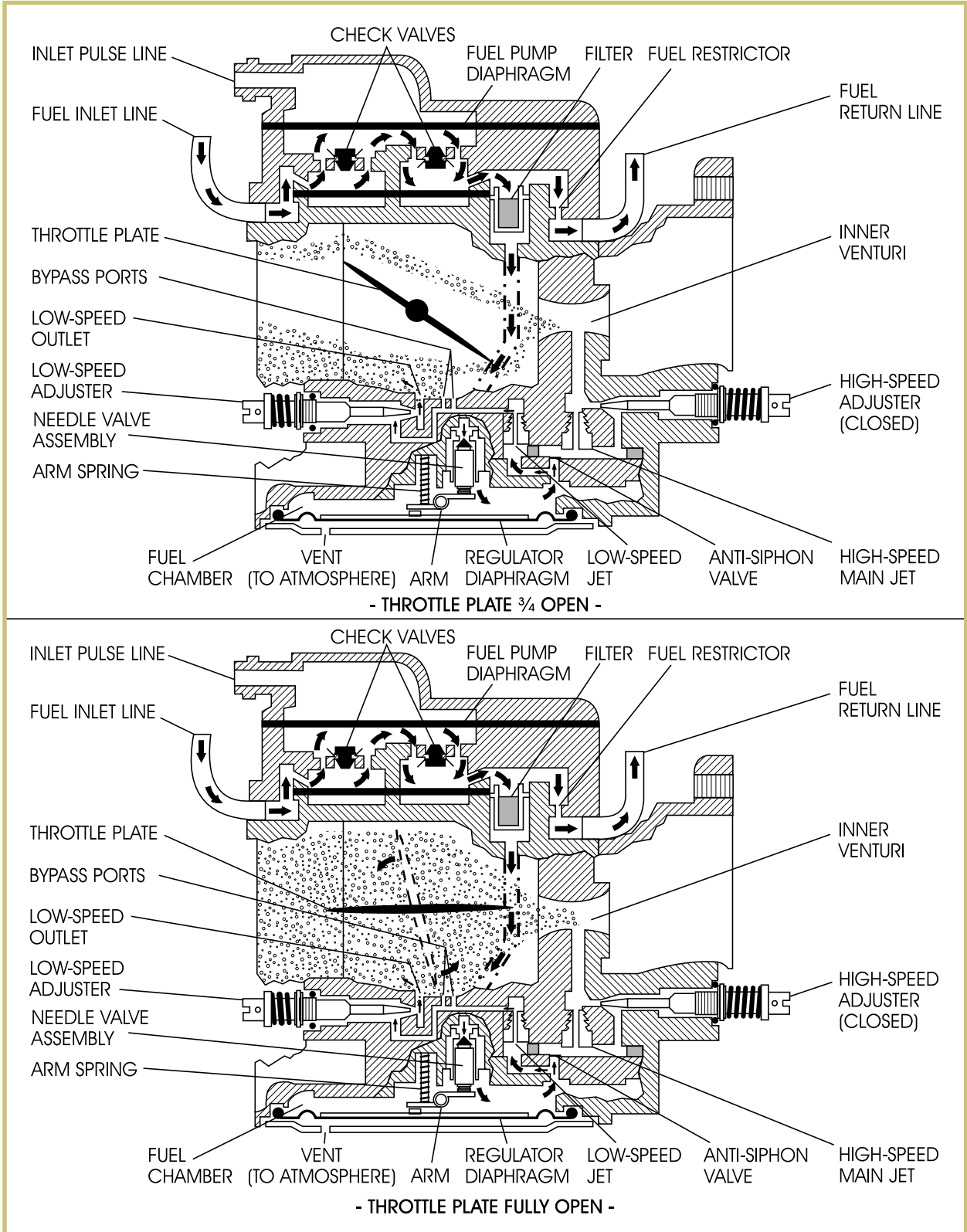
When the engine is idling, fuel is forced through the low-speed jet to the low-speed outlet. In order for the machine to idle, fuel must flow through the bypass ports and the low-speed adjuster. The low-speed adjuster is responsible for the fuel flow when the machine is idling. A properly tuned machine idles smoothly and has a quick initial throttle response.

As the throttle valve opens, low-speed bypass ports are increasingly exposed to the flow of incoming air (Figure 14). As covered in a previous study unit, their function is to help the carburetor transition from low-speed to high-speed operation. They prevent the engine from bogging down and hesitating. The size of the low-speed jet affects the flow of fuel through the bypass ports for low-speed operation. Also, low-speed performance is affected by the regulator portion of this type of carburetor. The regulator portion can be tuned to suit the conditions of the watercraft.

As the carburetor transitions to its high-speed fuel circuit (at about  $\frac{1}{2}$  throttle), fuel is drawn through the anti-siphon valve, and then through the high-speed (main) jet (Figure 15). The purpose of this anti-siphon valve is to prevent fuel from flowing through the high-speed circuit during idle and at small throttle openings. Fuel from the high-speed jet passes through the inner venturi, then into the engine. The high-speed adjuster controls the maximum amount of fuel flow for full-throttle performance ( $\frac{3}{4}$  throttle to wide-open throttle), as Figure 15 illustrates.



**FIGURE 14—A cross section of a fixed venturi carburetor at idle and with the throttle plate 1/4 open is shown here. At the 1/4 open stage, the bypass ports become exposed and additional fuel is allowed to enter the engine.**



**FIGURE 15—A cross section of a fixed venturi carburetor with the throttle plate  $\frac{3}{4}$  open and wide open is shown here. At the  $\frac{3}{4}$  open stage, the main jet begins feeding the carburetor and the increased velocity draws the fuel into the inner venturi. At the fully open stage, all fuel-feeding ports are exposed and the maximum amount of fuel is entering the engine.**

## Fuel-Pressure Regulation

One drawback of the fixed venturi carburetor is that it's sealed and can't vent the fuel chamber to the atmosphere. If a fixed venturi carburetor attempted to vent its fuel, the fuel would leak into the hull and create a serious safety hazard.

The Mikuni Super BN fuel chamber is controlled by the regulator diaphragm. Fuel is on one side of the carburetor and atmospheric pressure is on the other. Fuel in the chamber is drawn in by the pressure difference created by the engine. The diaphragm moves in response to the reduction of fuel, as well as the effect of the atmospheric pressure that's pushing against it. The diaphragm and the needle-valve arm allow fresh fuel to enter the fuel chamber. Fuel enters the chamber (under pressure from the fuel pump) with enough force to push the diaphragm back, even with resistance from the atmospheric pressure. When the fuel chamber is once again filled, the diaphragm relieves the pressure on the arm and the needle valve closes. This is how the diaphragm mechanism precisely regulates the amount of fuel in the fuel chamber.

As we mentioned earlier, the regulator portion of this type of carburetor primarily affects engine operation at throttle openings of 1/2 or less (in response to the engines, high manifold pressure). The regulator is an adjustable component and can be tuned to most engine configurations. The term most commonly used for this adjustment is pop-off pressure. *Pop-off* is a relative term that refers to the pressurization of the needle valve via compressed air, through the fuel inlet, and noting the pressure necessary to open the needle valve, or "pop" it off its seat. The higher the pressure that's required, the higher the pop-off pressure.

The Mikuni Super BN performs like a conventional carburetor as the throttle is opened through and past 1/2 throttle. This is achieved through replaceable jets and adjustment screws that make changes in fuel calibration. As the throttle plate is turned beyond 1/2 opening, the engine replaces manifold pressure with air velocity. Manifold pressure is the pressure difference generated by the engine, against a closed or nearly closed throttle plate. As the throttle is opened, the carburetor is no longer controlled by the regulator portion and responds as a normal carburetor does. The air velocity is drastically increased as the engine revs, creating the venturi effect (or low pressure) within the carburetor venturi. As we know from past study units, fuel flow through the carburetor is caused by the differences in pressure between higher atmospheric pressure on the diaphragm and lower pressure within the carburetor venturi. The air velocity creates such a strong pressure difference, the pop-off pressure has virtually no effect on calibration past 1/2 throttle. Accurately tuning a fixed venturi carburetor requires understanding all of its functions and following a few basic rules.

*Note:* The carburetor will work only as well as your engine does. This means that the performance of a carburetor won't make up for a weak or worn-out engine.

## Electrical Circuits

The ignition systems found on personal watercraft are either AC or DC CDI systems that require no maintenance. The charging systems found on personal watercraft are permanent-magnet types and can be half-wave, full-wave, or three-phase systems. The basic function of the charging system is to keep the battery in a fully charged state. The electric starter motor is the primary electrical component that drains power from the battery. Most personal watercraft use AC lighting systems that are similar in design to those we've discussed in previous study units.

## Hull Configurations and Components

Personal watercraft hulls are constructed according to various designs (Figure 16). Some of the more common ones include

- A V-bottom with strakes, which provides a soft ride at high speeds
- A V-bottom with strakes and pad, which is the same as the V-bottom with strakes, except it has an additional pad to increase the top speed of the craft
- A tri- (cathedral) hull with pad is similar in design to a V-bottom with a pad. Hull outsides are added primarily in the forward section of the hull. This design is more stable at high speeds, but provides for a rough ride in choppy water conditions.

**FIGURE 16—Personal watercraft hulls come in different designs and configurations.**





Hull units consist of two pieces that are glued together and purchased as a single unit (Figure 17). Engine hoods cover the engine compartment and act as a ventilation system. As a result, engine hoods should never be modified. Sit-down models may use the upper hull, or even a portion of the seat, for engine-compartment ventilation.

Hulls on personal watercraft are considered to be self-righting. Three factors affect self-righting ability:

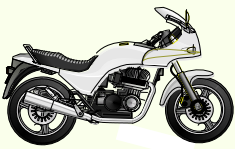
- Buoyancy, which is formed by the upper half of the craft (handlebar, engine hood, side rails). This is the displaced center of buoyancy.
- The center of gravity (CG), which on a personal watercraft is low because of the engine and drive line being placed in the lower half of the watercraft
- The *metacenter*, which is a point at the intersection of a vertical line drawn through the center of gravity and a vertical line drawn through the displaced center of buoyancy

**FIGURE 17**—A basic sit-down type personal watercraft hull with no other components is shown here.



Some watercraft hull designs contain a self-circling feature which allows a watercraft to circle when a rider falls off. When a rider falls, the center of gravity shifts forward on the craft. This causes the bow (front) to plow, and a combination of the handlebar position, idle rpm, and asymmetrical water flow at the bow holds the craft in a circling motion.

# Road Test 3



- 1. *True or False?* All watercraft have charging systems that use a permanent-magnet design.
- 2. The water in the \_\_\_\_\_ jet pump is brought in and discharged straight through the pump housing.
- 3. The water in the \_\_\_\_\_ jet pump is directed outward of the pump housing and then back to the center.
- 4. Which jet pump design is more efficient for low rpm use?  
\_\_\_\_\_
- 5. Which type of jet pump is best for high-speed applications?  
\_\_\_\_\_
- 6. Personal watercraft use the \_\_\_\_\_ type of carburetor.
- 7. How does an impeller on a personal watercraft differ from a propeller on a boat?  
\_\_\_\_\_  
\_\_\_\_\_
- 8. If the fuel system used on a watercraft is pressurized, how can there be ventilation to the atmosphere?  
\_\_\_\_\_
- 9. A point at the intersection of two vertical lines, one through the center of gravity and the other through the displaced center of buoyancy, is called the \_\_\_\_\_.

Check your answers with those on page 43.

## PERSONAL WATERCRAFT MAINTENANCE

Each personal watercraft service manual contains a periodic [maintenance chart](#) located in the general information or maintenance section of the service manual. Periodic maintenance is generally broken down into the following hours: 10, 25, 50, and 100 hours. We’ve provided a typical personal watercraft maintenance table for you to see. Remember, this is an example chart. Some watercraft require initial maintenance checks to ensure proper functioning.

*Note:* There are items that require the attention of the operator and others that need the attention of a technician.



EXAMPLE PERIODIC MAINTENANCE CHART					
Description	10 Hrs	25 Hrs	50 Hrs	100 Hrs	Performed by
Lubrication/corrosion protection	*		*		Operator
Ignition timing				*	Technician
Spark plug replacement			*		Technician
Throttle/choke cable inspection/lubrication	*	*			Operator
Flame arrester inspection			*		Technician
Carburetor adjustments				*	Technician
Oil-injection pump adjustment				*	Technician
Fuel filter inspection		*			Technician
Fuel filter replacement				*	Technician
Fuel tank straps	*				Operator
Oil tank straps	*				Operator
Engine head bolt torque				*	Technician
Steering system					Technician
Reverse system inspection			*	*	Technician
Trim system inspection					Technician
Fastener tightening (flame arrester, carburetor(s) engine mounts, exhaust system, etc.)			*		Technician
Muffler, battery, and reservoir fasteners			*		Operator
Fuel lines, check valve, and fuel system pressure test			*		Technician
Fuel vent line pressure-relief valve inspection		*	*		Technician
Inspect/clean engine drain tube	*	*			Technician
Bilge system/water tank trap drains inspection			*		Operator
Battery condition			*		Technician
Electrical connections		*			Technician
Impeller shaft reservoir oil level/condition		*		*	Technician
Impeller condition and clearance		*	*		Technician
Driveshaft condition			*		Technician
PTO flywheel lubrication	*				Operator
Water intake grate condition			*		Operator
Hull condition				*	Operator
Cooling system flushing (daily if used in salt water)		*			Operator

- Before you perform any maintenance on a personal watercraft, there are certain operational precautions that you must follow.
- Never operate a personal watercraft without cooling water for more than 15 seconds.
  - Always check for sand in the cooling system and exhaust manifold. Sand in the cooling system will cause overheating and is a good sign that the craft has been beached or run in water that was less than two feet deep.
  - When removing the battery, always disconnect the negative battery ground first.

- Never reuse a gasket or an O-ring.
- Never reuse retaining rings after you've removed them.
- Always use the manufacturer's recommended and approved chemicals; otherwise you may cause hull or paint damage.
- Never overload the tow-rope holes in the hull.
- Always route and secure all lines and electrical wires as per the service manual recommendations.
- Never let oily rags or chemicals sit in the hull for long periods of time.
- Never drag a personal watercraft across a concrete floor.
- Beware of corrosion near or around all engine grounds when troubleshooting electrical problems.
- Always roll the machine on the side indicated by the manufacturer to prevent the possibility of water entering the cylinders from the exhaust system.

## Hull Finish Care

When the hull surface has lost its luster, you must clean the surface with water and a neutral detergent. After the surface has dried, apply rubbing compound and then wax the hull to bring back the original shine and luster. If the hull is faded or scratched, use number 600–800 wet sandpaper to remove. Again, finish with rubbing compound and wax. Don't use an electric polisher to maintain the finish of a personal watercraft hull.

## Cooling, Bilge, and Exhaust System Service

### Cooling and Waterbox System

As we mentioned earlier, all personal watercraft use a total-loss cooling system. The cooling water originates on the high-pressure side of the impeller pump. The routing of the cooling system starts at the pump outlet, goes through a hose to the cylinder and cylinder head, and travels from the head through a hose to the exhaust-pipe elbow. Water from the exhaust-pipe elbow flows to the expansion chamber, then is sent to the resonator, if one is used. From the expansion chamber, the water then flows to the waterbox. The *waterbox* is the main muffler on the craft. On some models of personal watercraft, cooling water is routed from the exhaust manifold to the flywheel cover and then to the expansion chamber. In order to verify the movement of cooling system water, you can see the bypass outlet which is tapped

from the exhaust manifold. On some models, there are water jackets on the outside of the expansion chamber. If there's a problem with the cooling system, it results from a leak or a plugged passageway.

## Bilge System

The bilge system removes water from the engine compartment. This is accomplished with negative pressure from the jet pump (provided by a nozzle located at the pump), through the *breather*, which is the highest point in the system. During normal operation, the breather hole allows water to drain when the unit is shut off. If it doesn't, inspect the breather hole for blockage.

## Drive System

Personal watercraft use a direct-drive system, which makes the maintenance of these systems relatively easy. The drive shaft is supported by a bearing housing and impeller housing. Cavitation is the worst enemy of the drive system and is caused by water on the blade surface which is boiling from low pressure.

Most personal watercraft models use a self-centering bearing housing, which requires no shimming. This design uses one bearing and four separate seals. When replacing the bearings on this design, loosely mount the housing bolts, install the engine, and torque the housing mounting bolts to the manufacturer's specifications.

Some drive system bearing housings have a non-self-centering bearing design. This design has two bearings that require shimming to correct any excessive shaft end-play. To center the housing and driveshaft, remove the old silicone and shim between the housing flange and hull bulkhead until the shaft is within the manufacturer's specifications (on the top and sides), then seal the housing to the hull.

*Note:* Some models incorporate an access panel to inspect the drive-line housing.

## Pump Assembly

The jet pump impeller case has guide vanes that straighten out the water, which prevents the hull from torquing to one side during acceleration. Most impellers employ three to five blades. The nozzle accelerates water and increases thrust, while the steering nozzle is used for directional control.

As you know, there are two types of jet pumps used on personal watercraft, an axial flow and a mixed flow. The axial-flow design has water flow through the impeller that's parallel to the axis of the impeller. The impeller has a wing-shaped impeller blade that lifts the water. This system uses a non-shim impeller. If there's excessive tip clearance, the component will need replacement. The mixed-flow design allows

water to flow through and is inclined to the impeller axis. Both lift and centrifugal force are applied to create a high-pressure pump. The impeller tip clearance is adjustable on the mixed-flow jet pump. In order to improve low rpm thrust, adjust the impeller tip clearance. On a mixed-flow pump design, shims are used on the drive shaft to move the impeller into the proper clearance range. Check the tip clearance with a feeler gauge and adjust the shims as needed to get the proper specified clearance.

*Note:* The jet pump used on a personal watercraft seldom needs any maintenance. The impeller needs clearance verification and inspection for damage from debris entering the pump housing.

## Personal Watercraft Driveshafts

Driveshafts are made in either one-piece or two-piece designs. One-piece designs are contained in the impeller housing and supported by a bushing. An improperly aligned pump will damage the bushing in a one-piece designed driveshaft. A two-piece driveshaft allows the pump assembly and impeller to be removed as one complete unit. The impeller is screwed onto a secondary shaft, which is supported by two bearings. The main driveshaft contains splines that attach it to the impeller. All pump housing mating surfaces must be properly sealed.

### Reverse

Some personal watercraft use a reverse gate attachment ([Figure 18](#)) which allows the craft to be “shifted” into neutral and reverse. These attachments are cable-actuated. An occasional adjustment may be needed. The cables don’t require external lubrication.

**FIGURE 18—Reverse Gate Attachment of a Personal Watercraft**



## Directional Nozzle

The directional nozzle (Figure 19) is also cable-actuated in a manner similar to the reverse gate system. Again, there are times when an adjustment to the cable will be needed, but no lubrication of the cable is required.

**FIGURE 19—Directional Nozzle of a Personal Watercraft**



## Carburetor Adjustments

The available adjustments for fixed venturi carburetors are in the low-speed and high-speed mixture screws. Some models also have a midrange adjustment screw. These screws are set to the individual manufacturer's specifications, which can be found in the appropriate service manual. When you make carburetor adjustments on a personal watercraft, place the craft in water and adjust the carburetor in the following sequence:

1. Set the idle rpm. This is achieved with the idle stop screw. The idle stop screw adjusts the idle by opening or closing the throttle body butterfly valve. The service manual will provide the factory-recommended engine rpm, but as a rule of thumb, this adjustment is around 1500 rpm.
2. Set the pop-off pressure. This requires the use of a small pump in conjunction with an air pressure gauge. To test the pop-off pressure, a pump hose must be attached to the fuel inlet while the fuel return line on the carburetor is plugged. Normally, the diaphragm and its cover are removed during this test. Ensure that the needle valve is wet at all times, and pressurize the carburetor with the pump until the needle valve pops off. Then check to see at what pressure the valve closes and reseals. Test this at least three times

to ensure consistent readings. Refer to individual manuals for specifications.

3. Set the low-speed adjuster screw. This screw should be set to maintain the idle speed and to keep the engine running smoothly at low engine rpm. As the idle speed is adjusted, the low-speed mixture screw is also affected. Turning the screw in a clockwise direction causes the mixture to become more lean because it closes off the fuel from the carburetor. Turning the screw in a counterclockwise direction causes the mixture to become richer.
4. Set the midrange adjuster screw (if applicable). Some personal watercraft have a midrange adjuster screw that's adjusted in the same manner as the low-speed screw. This screw should be set to throttle.
5. Set the high-speed adjuster screw. This screw should be set for full-throttle operation. The high-speed adjuster screw is used in conjunction with the main jet. Rotating the screw clockwise causes the mixture to become lean. Rotating the screw counterclockwise causes the mixture to become richer.
6. Return the engine to idle and recheck the rpm after making all adjustments.

The reason for this sequence of adjusting the carburetor is that the circuits tend to overlap one another and contribute to the total fuel delivery to the carburetor. For example, changing the low-speed jet will have an effect on the fuel delivery at full throttle.

## Fuel Pumps

The fuel pumps used on personal watercraft are either internally or externally mounted units that are operated by crankcase pressure. Other than checking the lines for cracking, there's no maintenance required for these components. The only maintenance that's required is inspecting the fuel lines for damage.

### Fuel Lines

The fuel petcock supplies fuel to the fuel filter and then to the carburetor through fuel lines. On twin-carburetor models, the return line from the main carburetor feeds the second carburetor. The return line from the second carburetor returns to the fuel tank. On triple-carburetor models, the return lines from the first and third carburetors feed the second carburetor. The return line from the second carburetor returns to the fuel tank. The vent line from the fuel tank has a one-way check valve that can easily be checked via a pressure pump. The appropriate service manual will give you the proper specifications to test this valve.



## Fuel Filters

Fuel filters will allow water to pass through them and should be cleaned and inspected as part of any routine service. In order to prevent any air or water leaks, ensure that all O-rings and seals are properly installed on the fuel filter. In addition to the one-piece disposable filter, some personal watercraft models have filter screens on the end of the fuel tank feed line. This serves as a final precautionary measure to prevent dirt from entering the carburetor. Some carburetors also incorporate a filter screen in the fuel-supply circuit of the carburetor.

## Electrical-System Service

The battery in a personal watercraft is used for the starter, gages, and trim adjustments. It's virtually identical in design to a standard battery that's used on a motorcycle except for its ventilation system, which uses a design similar to the maintenance-free battery. Most personal watercraft have a CDI-type ignition system. These systems may be AC- or DC-powered. All of these systems use an electronic advance system that's built into the ignition. The timing on these machines may be preset at the factory or can be set with a dial indicator and a timing light.

Normally, the charging systems used on personal watercraft are the full-wave permanent-magnet type. These charging systems may also be half-wave or three-phase systems. The charging voltage should normally be within 13–15 VDC, while the craft is at approximately throttle. Personal watercraft use an electric starting system that contains a waterproof starter motor. Conventional starters use a bendix system that requires no outside lubrication.

## Rev-Limiter

Rev-limiters are used to protect the engine from the damage that results from an engine that's revved past the manufacturer's engine redline. There are two basic ways to limit engine rpms:

1. Flood the carburetor with an excessive amount of fuel (through a solenoid switch, triggered by the CDI box). This type of rev-limiter routes fuel from the return line hose back to the intake track.
2. Prevent a spark from occurring at the spark plug. This type of rev-limiter is located in the igniter box, and at a predetermined engine rpm, grounds the ignition trigger circuit.

## Engine-Overheating Limiter

Some watercraft have a feature that limits the engine rpm if the engine temperature gets too hot. When used, this system limits the engine rpm to approximately 3,500 through a temperature sensor that’s located in the cooling system bypass hose and the CDI system.

## Troubleshooting Symptoms

The following is a list of common symptoms of trouble found on personal watercraft along with the most likely cause of the problem.

Troubleshooting Table		
PERSONAL WATERCRAFT		
Trouble	Possible Problem Area	Probable Cause
Engine hard to start, won't start, or starts then immediately shuts off	Outside carburetor	<ul style="list-style-type: none"><li>• Fuel line clogged or pinched</li><li>• Pulse line leaking or restricted</li><li>• Fuel filter plugged</li><li>• Fuel tap screens plugged</li><li>• Vent line restricted</li><li>• Fuel pump faulty</li><li>• Low engine compression</li><li>• Fuel cock not primarily operating to one fuel port</li><li>• Return line restricted</li><li>• Flame arresters plugged</li><li>• Choke improperly adjusted</li><li>• Fuel sediment bowl leaking</li></ul>
	Inside carburetor	<ul style="list-style-type: none"><li>• Diaphragm and/or system damaged or improperly adjusted</li><li>• Mixture screws improperly adjusted</li><li>• Water in carburetor</li><li>• Fuel passageways plugged</li><li>• Pop-off pressure incorrect</li></ul>
Engine misfires	Fuel mixture too lean	<ul style="list-style-type: none"><li>• Mixture screws improperly adjusted</li><li>• Obstruction in fuel-feed system</li><li>• Diaphragm and/or system damaged or improperly adjusted</li><li>• Carburetor loose</li><li>• Pop-off pressure too high</li></ul>

(Continued)



Troubleshooting Table—Continued		
Engine misfires	Fuel mixture too rich	<ul style="list-style-type: none"><li>• Mixture screws improperly adjusted</li><li>• Diaphragm needle tip damaged</li><li>• Choke on</li><li>• Flame arrester plugged</li><li>• Pop-off pressure too low</li></ul>
Engine won't idle but will accelerate	Carburetor	<ul style="list-style-type: none"><li>• Mixture screw improperly adjusted</li><li>• Idle jet or port plugged</li><li>• Throttle plate loose or improperly adjusted</li><li>• Pop-off pressure incorrect</li></ul>
Engine won't accelerate but will idle	Carburetor	<ul style="list-style-type: none"><li>• Mixture screw improperly adjusted</li><li>• High-speed jet or port plugged</li><li>• Diaphragm and/or system damaged or improperly adjusted</li><li>• Choke on</li></ul>

## Personal Watercraft Storage

Many personal watercraft owners depend on their local watercraft service department to prepare their machine for storage during the off-season. As a result, you should become familiar with the steps for preparing a personal watercraft for storage.

### Step One: Preparing the Watercraft

Before you begin preparing any watercraft for long-term storage, review the storage procedures in the appropriate service manual and adhere to all warnings and cautions. Ensure that you have all of the special tools and supplies specified in the service manual available to you. This prevents interruptions and decreases the amount of time you'll need to perform the job. Additional supplies you may need include the following items:

- A garden hose and an adapter with a 3⁄8-inch or 7⁄16-inch fitting
- An air compressor with an air-blower nozzle
- A siphon hose and hand pump
- An appropriate container for draining fuel
- A high-quality multipurpose spray lubricant
- A high-flashpoint solvent
- Baking soda

- Distilled water
- A high-quality wax
- A high-quality multipurpose grease and a grease gun
- A pressure cable lubricator (the same as used on motorcycles and ATVs)
- A new set of spark plugs
- Plenty of shop towels
- A mat to set the watercraft on

## Step Two: Preparing the Cooling System

Personal watercraft manufacturers recommend starting the storage process by flushing sand and salt from the cooling system. Often, machines have cooling hose adapter fittings on the cylinder head that allow you to tap directly into the cooling system without removing any hoses. Now, the  $\frac{3}{8}$ -inch or  $\frac{7}{16}$ -inch adapter comes into play. When flushing the cooling system, follow the individual manufacturer's procedures to prevent water from backing up into the engine. If this occurs, major engine damage is likely to occur.

The general procedure to follow when flushing the cooling system on a personal watercraft is as follows:

1. Attach the garden-hose adapter to the proper fitting on the cylinder, exhaust, or cooling hose.
2. Start the engine and let it idle.
3. Turn on the water at the faucet and adjust the flow of water until it just begins to trickle out the bypass outlet on the side of the hull.
4. Flush the cooling system for about five minutes.
5. Turn off the water.
6. Lift the rear of the craft about 8–10 inches and slightly rev the engine (no longer than 15 seconds) to expel the remaining water from the exhaust system.
7. Stop the engine.
8. After the engine has cooled off, restart it and rev it again to ensure that all of the water has been removed from the exhaust.

*Note:* Most service manuals will provide a procedure to remove the excess water using compressed air. However, several revs of the engine will remove the water from the exhaust, and the heat will evaporate the remaining residual water.

### Step Three: Checking the Bilge Lines

Attach the garden-hose adapter to the bilge filter hose and run water through it for a minute or so, flushing the bilge lines of any obstructions. Water will accumulate in the engine compartment while you perform this procedure. Tilt the watercraft onto the manufacturer's designated side when emptying the engine compartment. Once this procedure is completed, reconnect and tighten the bilge-hose clamps.

### Step Four: Checking the Fuel System

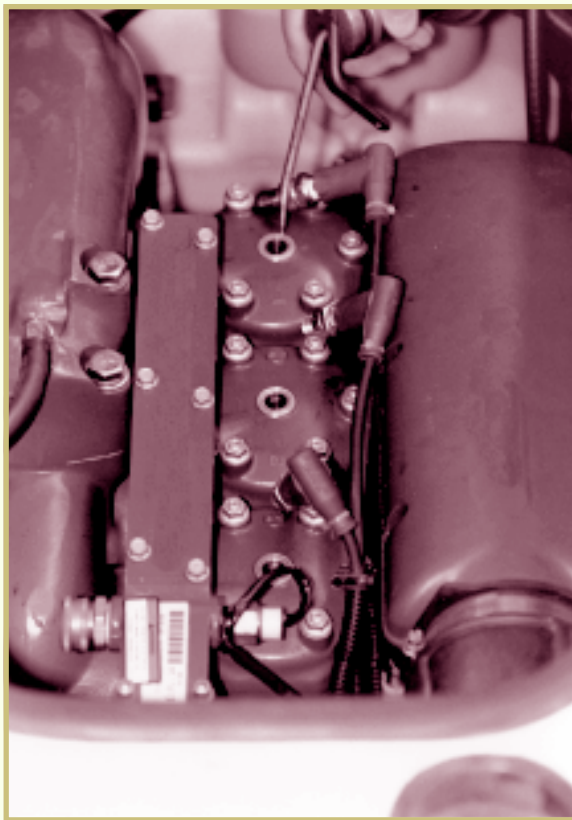
Remove the fuel tank and drain any fuel into an appropriate container. Sand and water may have entered the fuel tank during the season, so it must be thoroughly cleaned using a high-flashpoint solvent. Some models have sediment bowls and fuel filters installed on or near the fuel tank; these must be drained and cleaned or replaced. Be sure to properly install all O-rings to prevent any air from entering the system. Remember, the fuel system must be airtight to operate properly. If there are leaks in the fuel system, the fuel pump will suck air into the system, which can cause engine failure.

After the fuel has been drained, start the engine and run it for about 15 seconds and shut it off. Repeat this start-and-stop procedure until all of the excess fuel has been used and the engine will no longer run. Once the fuel has been removed from the lines and burned in the engine, remove the flame arrester and clean it with soap and water. Spray some multipurpose lubricant into the mouth of the carburetor bore and reinstall the flame arrester.

### Step Five: Lubricating the Internal Engine

To lubricate the cylinder walls, remove the spark plugs and pour about one tablespoon of motor oil into each spark plug hole ([Figure 20](#)). Push the starter button to turn the engine over, to thoroughly lubricate the cylinder walls. Remember to leave the spark plugs out of the cylinder heads, but be sure they're grounded properly against the cylinder head or exhaust manifold to prevent ignition damage. After you've lubricated the engine cylinder walls, reinstall the spark plugs and have a new set handy for the next season. Chances are, the current spark plugs won't start the craft when it comes out of storage (due to the added oil in the cylinder).

**FIGURE 20—Pouring oil in the cylinders will prevent corrosion of internal components. Note that the spark plugs are grounded to the cylinder heads, preventing any ignition problems.**



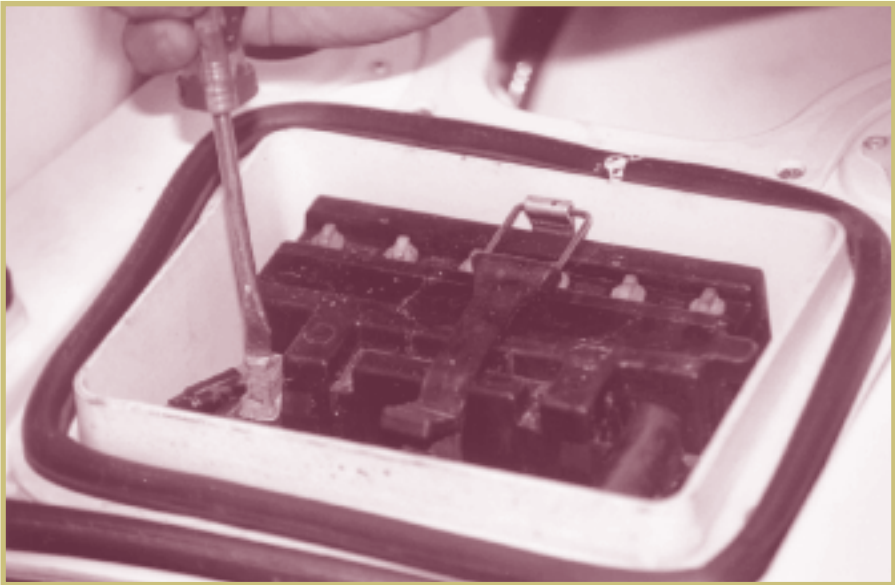
## Step Six: Preparing the Battery

Remove the battery from the watercraft by disconnecting the negative cable first ([Figure 21](#)) and then the positive cable. Clean the outside of the battery with a solution of baking soda and water (to neutralize any acid on the outside of the battery) and then rinse it with water. Check the water level and fill the battery with distilled water, as needed. Charge the battery, with a trickle charger, once a month while it's out of the watercraft and grease the terminals to prevent corrosion buildup.

## Step Seven: Preparing the Cables and Cleaning

Lubricate the throttle and choke cables with a pressure cable lubricator and apply grease to the cable ends. Check the steering cables for any damage, and grease the cable ball joints. Lubricate the pivot points on the steering nozzle ([Figure 22](#)). Wash the watercraft using a mild soap, and dry it thoroughly. Drain the engine compartment after you wash the craft, and apply a high-quality grade wax to the fiberglass. Spray all exposed metal parts with a high-quality multipurpose lubricant. Install the engine cover on the hull, but be sure to allow for ventilation. Finally, cover the craft and store it in a clean, dry environment.

**FIGURE 21**—When removing the battery from the watercraft, always remove the ground cable first to prevent sparks.



**FIGURE 22**—The technician in this photo is lubricating the pivot points of a nozzle.



### Step Eight: Preparing the Watercraft for Use

If the watercraft was properly prepared for storage, it should be in good condition when it's time to ride again. No matter how well a watercraft has been prepared for storage, the cold winter months can still take their toll. Inspect the watercraft hoses and connections for weathering or cracking. Be sure to check all cable-operated components, verifying that condensation didn't harm them while the watercraft was in storage. Before installing the battery, ensure that it's fully charged. After mounting the battery, coat all cables and terminals with grease to prevent corrosion. Fill the fuel tank, top off the oil tank (when applicable), and start the engine. Let it run for 15-second intervals and be sure to

let the engine cool off between starts. After starting the machine a few times, replace the spark plugs. Don't install new spark plugs before starting the engine; this will prevent fouling a new set of spark plugs (from the oil installed in the cylinders). Finally, clean and buff out the wax on the personal watercraft.

# Road Test 4



- 1. Another name for the main muffler on a personal watercraft is the \_\_\_\_\_.
- 2. *True or False?* All personal watercraft carburetors use a low-speed adjustment screw.
- 3. What is the “bilge system” on a personal watercraft used for?  
\_\_\_\_\_
- 4. What causes cavitation in the drive system on a personal watercraft?  
\_\_\_\_\_
- 5. *True or False?* All personal watercraft carburetors have a midrange adjustment screw.
- 6. What are the two ways that personal watercraft manufacturers limit the rpms (rev-limiters) on watercraft?  
\_\_\_\_\_
- 7. In order to lubricate the cylinder walls on a personal watercraft, when preparing it for storage, you should pour about \_\_\_\_\_ of motor oil into each spark plug hole.
- 8. A \_\_\_\_\_ should be used to charge a battery once a month while it's in storage.
- 9. *True or False?* Engine hoods should be modified to personalize watercraft.
- 10. The charging voltage for a correctly functioning personal watercraft charging system will show a voltage of \_\_\_\_\_ to \_\_\_\_\_ VDC at approximately throttle.

Check your answers with those on page 43.

# Road Test Answers

## 1

1. transmission, drive
2. V-belt
3. Hypoid gear lubricant
4. jackshaft
5. air-, fan-, or liquid-
6. True
7. engine
8. False

## 2

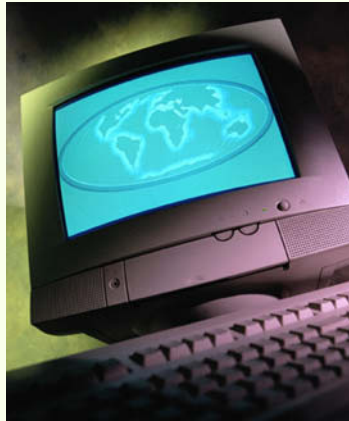
1. False
2. plow through the snow
3. dart from one side to the other
4. Premature belt wear
5. The clutch alignment
6. Remove the V-belt and rock the secondary clutch back and forth.
7. Main seal or gasket
8. Ruler and spring gauge
9. Alcohol
10. Engine fogging

## 3

1. True
2. axial-flow
3. mixed-flow
4. Mixed flow
5. Axial flow
6. fixed venturi
7. Impellers push water, while propellers pull water.
8. Through the use of a check valve
9. metacenter

## 4

1. waterbox
2. True
3. To remove water from the engine compartment
4. Boiling water on the blade surface, caused by low pressure
5. False
6. By flooding the carburetor and preventing the spark
7. one tablespoon
8. trickle charger
9. False
10. 13, 15



## ONLINE EXAMINATION

**For the online exam, you must use this**

**EXAMINATION NUMBER:**

**03302100**

**When you're confident that you've mastered the material in your studies, you can complete your examination online. Follow these instructions:**

1. Write down the eight-digit examination number shown in the box above.
2. Click the **Back** button on your browser.
3. Click the **Take an Exam** button near the top of the screen.
4. Type in the eight-digit examination number.